HIGH-SECURITY, PAID, AUTOMATED SMART PARKING DESIGN FOR A LARGE OFFICE PARK

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SUMMARY

An original, futuristic, permission-based-access, automated, gated parking system design for a large office park is described. The proposed system uses WiFi cellular phones as the primary access technology, license plate recognition via image processing as the secondary technology, keypad entry as the third technology, and verbal interchange as the last resort. The office park encompasses 20,000 employees and has 132 access points to parking lots. The strict access policy creates a high security office park. Implementation cost is estimated at $5.9M. A $0.50 per day parking charge per car is proposed, generating $1.9M per year in offsetting revenue.

INTRODUCTION

This paper provides a smart parking system design / "concept of operations." While Palo Alto's Stanford Research Park (SRP) is the focus, components of this scheme may be applied to other large office parks. This design is intended to be a credible conceptual start that could serve as the basis for a detailed design and parking study.

STANFORD RESEARCH PARK

Stanford Research Park (SRP), located in Palo Alto, California, is counted among the world's leading scientific research employment centers. Also known as the "parent of Silicon Valley," SRP has served as a model for numerous succeeding office parks. The 1,000-acre park boasts 161 buildings serving 160 companies, the twenty largest of which account for more than 90 percent of the park's 20,000 employees. Employers cover a broad spectrum of activities: energy research, personal computer manufacturing, medical systems, defense, bioscience, technology law, management consulting, information systems, electronic commerce, veterans' hospital, and research laboratories. There are 132 SRP parking lot access points, counting by hand from a high definition aerial photograph.

SRP is primarily owned by Stanford University. Many tenants follow an informal "40/40/20" rule on office development: 40% of total area must be dedicated to landscaping, 40% to parking, and up to 20% for one or two-story buildings.

For the purposes of this paper, we consider SRP to be "greater SRP", encompassing two additional office "super blocks," twelve adjacent blocks of convenient retail, and the Caltrain commuter rail station.

SRP experiences significant traffic congestion, and its Page Mill Road / El Camino Real intersection is Palo Alto's busiest, with 43,000 car trips per day for all directions combined. Stanford finds it difficult to add new development to SRP because of traffic impacts requiring significant mitigation.

PARKING DEMAND

Willson's studies of five suburban office parks found an average of 49 percent empty parking spaces at peak utilization. (1) When the early research parks were built, land was inexpensive, so surface parking was preferred. Thus, there is a large opportunity to manage parking spaces more efficiently and make better use of the land.

SRP weekday peak parking demand is calculated as 14,600 parking spaces. Currently, there is about 1 parking space per employee in the research park: 20,000 spaces in all. Thus, there are roughly 5,400 unused parking spaces representing roughly 44 acres of land (assuming 350 square feet per parking space).

Normally, landowners prefer to hold some excess in parking, to ensure that there is sufficient parking should a building use change. For instance, changing a building use from software development to a call center results in more employees per leasable square foot, generating increased parking demand.

In addition, landowners also like to provide a "cruising reserve:"

> *"It is not practical to provide parking on the assumption that every space will be fully utilized. Some reserve capacity is needed to allow for cruising vehicles in search of a space, vehicles un-parking, and for peak surges. Thus, a design safety factor should be applied to account for these conditions. A design safety factor of 10 percent is suggested for most land uses."* (5)

APPLICATIONS

Potential applications of this design are fourfold:

1) **High security**: Inexpensively provide consistent, high-security access to an office park, while still allowing cross-traffic on arterials that penetrate the area. With the current interest in Homeland Security issues, there is increased call for improved protection for both employer property and employees.
2) **TDM**: Implement as part of an ambitious transportation demand management (TDM) effort where reduced parking demand will allow for real-estate densification. This is especially appropriate for office parks that are built-out and face significant traffic mitigation costs for additional office construction. A very aggressive TDM program

could implement small parking charges and gradually increase the charges to reduce demand.

3) **Transit circulator**: Provide the parking system in parallel with advanced feeder/circulator transit service for an office park, where transit vehicle access is also permission based. Allow autos to park at outer edge parking lots where commuters use the circulator to navigate the last portion of the trip to their office from that lot. Details of an advanced circulator proposal for SRP are provided in the author's TRB '04 paper. (6)
4) **Tight supply**: Where parking supply is tight, direct employees to available parking spaces, eliminating unproductive time spent cruising for spaces. SRP is not currently supply-limited, but could be in the future. Microsoft's Redmond campus in Washington State is well known for its limited parking supply.

OBJECTIVES

Large office parks usually lack accurate data on the number of cars that are parked at any point in time. Often a parking count study is conducted on an irregular basis. A modern parking system can easily provide an instantaneous count of the number of parked vehicles. This accurate quantification provides valuable information that can be used to justify land use changes.

The sheer scale of SRP facilitates implementation of a state-of-the-art parking system. A phased, collaborative approach is advised.

Converting from unrestricted parking to automated, gated operation is a significant task, requiring additional expenses that are avoided when building from scratch. Most SRP lots allow rapid, unconstrained access and egress; consequently, a reservoir of space to buffer human interaction with access gates is missing. In many of these lots, an average gate interaction time of three seconds would have the undesirable result of backing up traffic into street bike lanes during morning peak. Adding more gated lanes to solve queuing problems is an expensive option that is not explored further. For reference, free flowing access lanes serve 500 cars per hour, exit lanes serve 250-400 cars per hour. "In converting from unconstrained to gated, the concern is usually more with entering, rather than exiting, cars," points out a McGann Parking employee.

PARKING SYSTEM GOALS

- Driver-friendly transition from free to paid parking. Minimize irritation with gates. Manage access/egress queues so that traffic flows smoothly.
- Provide ability to escalate security during high terrorism threat
- Provide a system that not only works well for recurring parkers (employees), but also for the transient populations (customers and visitors). While high income, credit card-toting technology workers may be relatively easy to serve with advanced technology, ensure that non-English-speaking, cash-only contractors also have successful interactions.

- Enhance SRP security, while allowing individual companies the flexibility to "layer in" additional security measures.
- Successfully support the few high turnover sites within the greater research park such as the movie theatre, banks, and computer store.
- Minimize capital and operational costs.
- Minimize disruption during system installation – minimize asphalt and concrete projects that tie up lots.
- Operate lots without human attendants
- Operate most lots without parking enforcement – make it impossible to violate the parking rules.
- Allow the flexible sharing of parking lots between adjacent employers
- Follow an open systems approach with ability to enhance system capabilities. Avoid being locked into proprietary technology.
- Select technology that can also be used for employee ID badges / building access control.

PARKING AUTOMATION TECHNOLOGY

Parking technology is undergoing a renaissance, thanks to new ITS (Intelligent Transportation Systems) technology. Each year performance is improving and price is dropping. New technologies are being validated as reliable, user-accepted, and cost-effective. The optimal SRP automation system will evolve as each year passes.

No matter which automation technologies are deployed, one important system component is to rapidly identify either the vehicle or the driver. Once a unique identification number is known, then centralized control and billing can occur.

CELLULAR TELEPHONY

There are a number of cell phone technologies that can identify a unique phone to the parking lot gate: WiFi (IEEE 802.11), Bluetooth, and cellular communications combined with GPS. Many current phones lack these features, but adoption is progressing rapidly. The first two short-range communications systems can only provide identification within their limited communications range. As the employee approaches the gate, a WiFi or Bluetooth radio signal is used to verify the employee's identification.

Because cellular has a global range, location information must be supplied to recognize that a phone is within proximity of the gate. The Federal Communications Commission "E-9-1-1" Mandate has caused cellular carriers to begin implementing "location tracking services." This service is typically provided via GPS chips within the handsets.

In contrast to technologically-limited, often-proprietary parking system hardware, cellular telephones provide an expandable, general purpose software platform that is open to unlimited software development. The four previously described applications of this parking scheme are well served by cellular technology:

- For "high security" applications of this parking scheme, cellular phones provide a graphical user interface, keypad data entry, and reliable communications. This facilitates the development of stricter access protocols, such as having employees key in a passcode on their phone.
- For the "TDM" application of this parking scheme, such phones can be deployed for additional intelligent TDM applications, such as facilitation of carpool connection-making and car sharing car access/entry. (6) Cellular phones enable the counting of passengers per car, allowing carpooling performance to be readily tracked and facilitating the implementation of carpool incentive programs.
- For "advanced circulator" applications, the cellular phone can also serve as an access device for the transit fare gate.
- For "tight supply" applications, the cellular user interface is well suited for automated communication of available parking spaces.

GPS phones are also useful in augmenting parking lot security (see section below entitled Parking Lot Safety).

There are numerous data protection / privacy issues associated with GPS cell phones that are avoided in this paper.

TRANSPONDERS

Transponders are now common in the Bay Area, used in the FasTrack electronic bridge toll collection system. One vendor provides credit card-sized, battery-free variants of the bridge toll transponders. These cost $22 apiece, read at slower speeds than 25 mph, and are well suited for parking lot operation. (7)

RADIO FREQUENCY IDENTIFICATION (RF ID)

RF-ID tags are small radio tags that may be attached to a vehicle. They operate in the same manner as cellular phone WiFi or Bluetooth identification. The current disadvantages of RF ID are cost, sensitivity to radio frequency interference, and possible confusion between two approaching vehicles. The emerging RF ID industry is working hard to address these disadvantages. The industry's stated objective is to lower the cost of RF ID to the point where individual clothing items may be tagged and tracked. Currently “passive tags,” tags without batteries, can be purchased for $2 in large volumes, and readers procured for $2,000 (plus mounting and power). Such passive tags may be read from a distance of 5 feet or less, so should be reliable in parking gate configurations. RF ID can offer accurate read reliability upwards of 99.7%.

LICENSE PLATE RECOGNITION (LPR)

LPR technology uses image processing to identify vehicles by their license plate numbers. A personal computer with a "frame grabber" card connects to video cameras focused on license plates. Once a video image is captured, algorithms detect the edges of the plate and then extract

numbers and letters from within this area. In California, about ten percent of cars do not have front bumper plates, so LPR systems must scan rear bumpers. LPR systems often capture images and illuminate bumpers using the infrared spectrum, to prove high accuracy during night time and overcast conditions. Out-of-state and dirty plates tend to frustrate these systems. For maintenance, video camera lenses require periodic cleaning. (8)

BARCODES

There are a number of automated barcode parking access systems in operation. One such system uses printed barcode stickers that are affixed to automobile glass (at a cost of two to ten dollars per sticker) and barcode reading hardware by the gate (at a cost of seven thousand dollars per unit). Barcode reading technology is generally more accurate than LPR. (9)

GATES, KEYPADS, KEYCARDS

Keypads allow drivers to roll down their windows and key in access codes to enter parking lots. Keycards require drivers to roll down their windows and insert a keycard into a reader box. "Contactless smartcards" are now available and are the same as RFID tags.

Gates enable all automation approaches and eliminate the need for most parking lot enforcement patrolling by keeping freeloaders and security threats out.

On access, a compuer display (LCD - liquid crystal display) indicates available spaces and provides feedback that the driver has been identified. On egress, the LCD indicates fare payment.

A turnaround in front of the access gate must be provided for the case when the lot is full.

ELECTRONIC MESSAGE SIGNS

Large Electronic Message Signs may be deployed in a few places within the research park to guide drivers to available spaces under conditions of tight parking supply.

SYSTEM SOFTWARE TECHNOLOGY

Parking access and egress hardware supports most identification technologies, often intermixed as optional modules in the same machine. It is assumed that such hardware may be easily modified to support newer wireless technologies. Once an identification system exists, the central control software can operate in many flexible ways, billing immediately or billing monthly via "credit card on file." Identification opens up new applications, such as automated time keeping for hourly workers.

One of the main benefits of automation is real-time reporting. An accurate parking count by hour can be generated with the click of a mouse.

All the hardware is self-diagnosing. In the control room, equipment anomalies are signaled with audible alarms to facilitate rapid human response and high system "up time." Modern parking control software features an interactive system map with moving gates and gate open/close override, anomalous event handling, credit card processing, car counts, revenue tracking, and central pricing control.

The control software can be customized in many ways. Central control room personnel can manage gates and intercom for a particular lot, or provide that same control to individual company security personnel via web access. Customization serves companies with a wide range of preferences. Innovative, custom pricing strategies are also easily implemented.

Central parking control can readily be provided in a single cubicle with a single workstation.

IMPLEMENTATION

The automation system design arises from a set of goals that are influenced by trends, available technology, special cases, and capital/operating costs.

TRANSPORTATION MANAGEMENT ASSOCIATION

To come about, this parking scheme will require enthusiastic support and cooperation from employers. A Transportation Management Association (TMA) should be formed to share and control all parking lots within SRP, and to control the parking access database. SRP does not currently have a TMA in place.

TECHNOLOGY RECOMMENDATION

The proposed system uses WiFi cellular phones as the primary technology, LPR as the secondary technology, keypad entry as the third technology, and verbal interchange as a last resort.

There are issues with adoption of cellular handset models and operators. Handsets should have compatible features to facilitate software development. It is expected that not all carriers will be supported. In addition, there are timing issues related to having employees cancel cellular contracts and switch over to the compatible handsets/operators.

ACCESS

A strict access policy, more strict than most employers currently implement, is described to demonstrate how unauthorized access is prevented, demonstrating that very high security may be provided by automation. The automation system will support many different access policies, with more relaxed policies being easier to implement. In actuality, the TMA will set parking lot access policies, and different parking lots may have different security policies.

The strict access policy will permit entry only to SRP employees in good standing and to pre-authorized transient visitors. Pre-authorization will be granted by a secure web application,

where SRP employees will grant access to visitors, typically providing a WiFi handset ID or the license plate number of the entering vehicle. In addition, the authorizer sets the starting time and duration for permissible access. Some visitors may not know their license plate in advance; for example, training program visitors who rent cars at San Jose Airport the morning of their visit. In these cases, the web-based pre-authorization application will provide a unique ID number that can be forwarded to the visitor for their keypad entry at the access gate. For a vendor who will be working on site for a few weeks, a single pre-authorization transaction will grant privileges for the entire duration.

The TMA and individual companies will set the rules about visitor payment: whether companies will pay for visitors, whether visitors will pay, or whether visitors will be provided with free parking. During pre-authorization, pre-payment may be easily arranged.

Two cumulative hours of free parking per day will be permitted for employees and transient parkers, after which a $0.50 parking charge will apply. Two hours provides a simple solution for visits from spouses, job seekers, and vendors.

Large electronic message boards and NextSpace (see the section entitled "NextSpace" below) guide drivers to available parking spaces within SRP.

At the access gate, the first step is to identify the driver. If a successful WiFi identification is made, then the system grants entrance to known SRP employees and people who have been pre-authorized based on their WiFi ID.

Multiple cars arriving at the access gate will simultaneously attempt to communicate with the access PC. The WiFi unit closest to the PC will be granted communications access.

If there is no WiFi-based admission, license plate recognition is attempted. If a license plate is successfully read and the plate has been pre-authorized, then entrance is granted and the LCD also indicates that access has been granted. Otherwise, the Access Denied message, "Access Denied, press '1' to speak to central control," is displayed. In the case where an SRP employee does not have a working WiFi handset, the system will also permit entrance based on LPR.

Combined WiFi and LPR should compute within 0.5 seconds, ensuring that entrance queues do not develop and back traffic up into the street.

If identification fails, the gate's LCD shows, "Enter authorization code for access. Press '1' to speak to central control." The driver may then enter an authorization code at the gate's keypad or speak with central control. Central control personnel will be able to view a video image of license plates that cannot be read, for secondary plate verification. For a visitor, central control will obtain the name of the SRP employee the driver is attempting to contact, and will verify authorization before admitting the driver. During peak hours, central control will instruct drivers to leave the parking lot entrance during the authorization process so as to not back up traffic.

The access system hardware is diagramed in Figure 1 below:

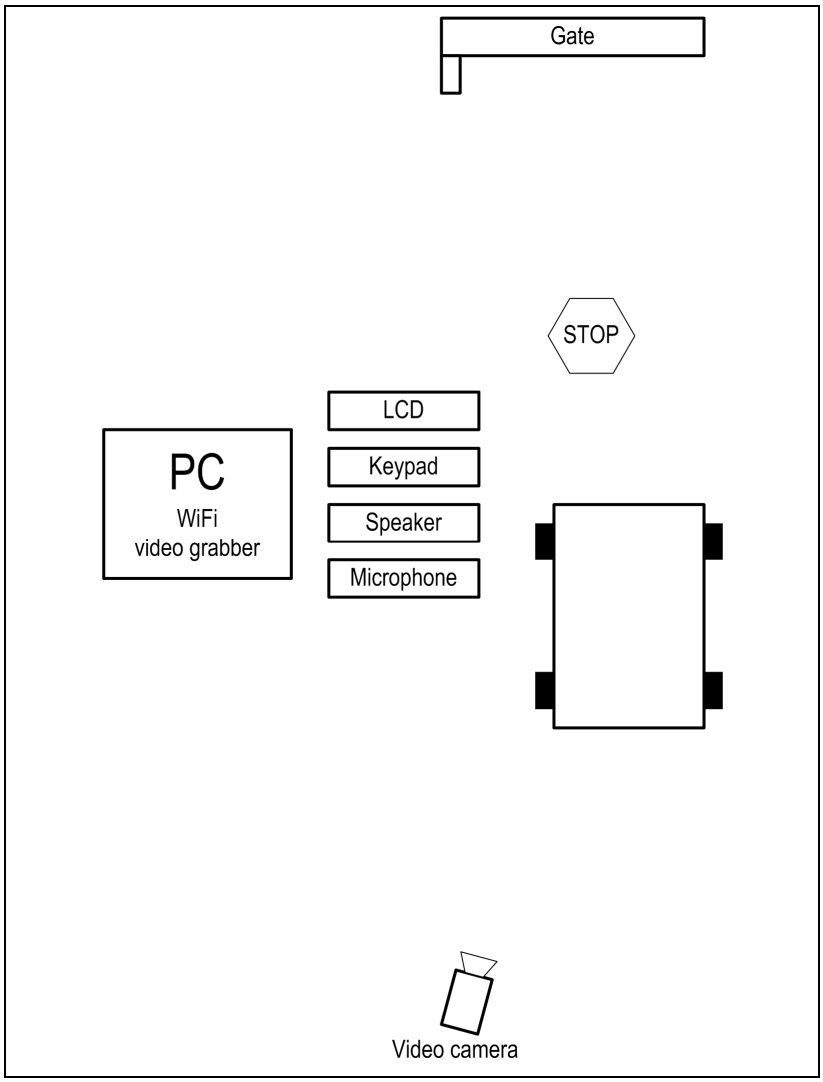

Figure 1: Access Hardware

The ruggedized PC controls operation and interface for Gate, LCD, Keypad, Speaker, Microphone, WiFi communications, and the video grabber. The PC, LCD, Keypad, Speaker, and Microphone are located in the "middle," 25 feet before the gate and 20 feet after the video camera. A Stop Sign combined with the LCD directs drivers to stop there to be identified. The 25 foot Gate/Stop Sign separation provides sufficient space for turnarounds. The video camera connects to the video grabber via an analog cable (a wireless connection would be preferable). The PC contains WiFi communications and the video grabber card. A large communications "pipe" connects this PC to the employer's network. The speaker and microphone are used for verbal communications with central control.

EGRESS

At the egress gate, WiFi and LPR identification is attempted.

First, if a successful identification is made and the driver / vehicle has parked for a cumulative total of less than two hours that day, then there is no charge and exit is granted. The LCD shows, "Have a nice day."

Second, if the driver / vehicle is identified with a stay longer than two hours, and $0.50 payment can be made, exit is granted and the LCD shows, "$0.50 charged to account # xxxx 1234. Have a nice day." A similar short message service (SMS) message is sent to the driver's WiFi cellular handset. Payment is possible for SRP employees who have parking system credit card accounts available for charges, and for pre-authorized IDs. $0.50 charges are logged each day and cleared once a month.

If the first and second cases do not hold, then the LCD shows, "Please enter exit code, press 1 to contact central control." If the driver supplies a valid exit code, then exit is granted. Otherwise, a verbal interchange with central control via the microphone/speaker pair is required. Depending on policy, the driver can either be granted exit or instructed to obtain authorization. With this high security system, any valid entrant should have a valid exit method.

Exit lane hardware is the same as found in entrance lanes.

TERRORISM PREVENTION / EXTRA SECURITY LAYERS

There are numerous ways to augment gated security checking during periods of high terrorism threat warning levels. In addition, temporary gate access at the office park's perimeter may be implemented. In addition, information about delays caused by additional security can be easily relayed to employee cellular handsets, providing information to make a better choice about when to commute.

When additional security checking is desired, it may be implemented for the entire office park, for individual lots, or via other selection criteria. Some of the additional checking methods that may be selected include:

- Layering in gate personnel to the access protocol, with central security information made available to gate personnel. Gate staffing may be rapidly added or eliminated.
- Upon WiFi or LPR authorization, the hand keying of an access passcode could be required. With cellular phones, the access passcode could be provided to the parking system while the employee is on-route or even before the employee leaves their home.
- Apply police background checking to all employees in the parking system database.

PARKING LOT SAFETY

The office park-wide TMA provides the scale to implement increased parking lot safety in a cost-efficient manner. The gates discourage unintended use of lots. Should advanced circulator transit be provided, then the parking system can consolidate evening parking into fewer lots, with more concentrated security.

In addition, GPS software can be used to reduce evening parking lot assaults by tracking the walk from the office to vehicle. Algorithms may detect events that could represent assaults, such as the handset veering away from the car, or the handset staying motionless for too long.

NEXTSPACE / SHARING PARKING SPACES WITH ADJACENT LOTS

There are three potential motivations for employers to allow employees from other companies to use their parking lots: a) to combat parking shortages at an adjacent parking lot where the employment destination is within walking distance, b) to accommodate special event overflow parking needs, c) where an advanced circulator allows parking at the edge of the office park with employees using the circulator to get to their work site.

For a typical company parking lot with X spaces, a company would like to reserve Y spaces for employees to ensure that each employee has a convenient parking space. This leaves $Z = X - Y$ available parking spaces for the parking system to allocate to non-company employees. The NextSpace cellular handset application directs employees to available lots during periods of tight supply. NextSpace eliminates the unproductive cruising for spaces in full lots. The NextSpace backend server application allocates the Z available spaces within each lot and adjusts that number as new, non-company employees enter lots. In addition, a few, large electronic message signs will also be deployed within SRP, to direct parkers.

"Full space-navigated parking" technology, such as has been implemented in Stuttgart, is readily deployable. Infrared readers for each parking space provide a full/available status, allowing drivers to be directed to open spaces, eliminating cruising. This design does not attempt to include this technology in the analysis, but a larger parking study might. (10)

RETAIL AREAS

Initially, for high-turnover retail establishments, extra care will be taken to ensure the system operates smoothly, preventing loss of customers. Parking attendants or mobile, meter-checking personnel will enforce two-hour, gateless parking.

SRP employees may be tempted to park all day in these two-hour spaces. Enforcement will prevent this. Un-gated all-day spaces may be specially signed and painted for employees.

The Palo Alto Square parcel combines office and retail with a movie theatre. This parcel features a large number of parking spaces. These mixed-use spaces should be gated, while also allowing two-hour free parking. To allow for movie viewing, the TMA would probably adjust the Palo Alto Square lot to have three hours of free parking.

The unattended Caltrain California Avenue station parking lot currently has a $1 per day charge. This can be kept as is, or made part of the TMA system with either a $0.50 or $1 charge.

FIFTY CENT DAILY PARKING

A proven TDM technique is to charge for parking. A database of 41 U.S. TDM case studies compiled by the Environmental Protection Agency revealed nominal suburban solo driving reductions of 16, 25, 28, 20, 16, 25, 34, and 25 percent with paid parking or parking cash-out regimens. (11) Charging $8 or more per day will significantly reduce solo driving to SRP.

In the Bay Area, no suburban office parks charge for parking, so bringing about any charge for parking, even $0.50 per day, will be difficult. Admittedly, the TMA may not be amenable to such a charge. However, such a charge could be brought about as part of an aggressive TDM program, should it be adopted. The master plan for the large, nearby Moffet Field Office Park requires each employer to either have employees pay "full cost" parking ($165 per month) or have employers cash them out. Unfortunately, implementation of this Moffet parking requirement has not yet begun.

An automated SRP parking system allows for small daily charges to be implemented economically. A $0.25 or $0.50 daily parking charge should not be very objectionable to the relatively affluent SRP workers, as it represents a tiny fraction of worker income. Such a small charge should not be not expected to cause a noticeable commute mode shift, though the added irritation of parking lot access and egress would drive some number of solo drivers to change mode. The charge could begin as $0.25, phasing in to a higher level after six months of operation.

Such a small parking charge should only reduce solo driving commutes to SRP slightly. More importantly, such a parking charge would make it more acceptable for other office parks to charge for parking. As adoption advances, such parking charges could be gradually increased, bringing about a small reduction in solo commuting demand with each increase. Thus ITS-based parking automation provides a relatively low-cost route to "sneak" parking charges into suburban office parks.

Though small, a $0.50 charge adds up to annual office park revenue of $1.9M, very significant in defraying the costs of the automation system. (Calculation: 14,600 daily peak parkers * $0.50 * 260 weekdays – this number should be increased slightly to account for off-peak parking.) The proposed parking system does not require paid parking; however, the system itself facilitates the implementation of paid parking.

EQUIPMENT MALFUNCTION

When a system malfunction occurs, such as a computer glitch or power outage, exit gates will open until a solution is achieved. In the interim, personnel from nearby offices should staff access gates. To reduce downtime, a maintenance contract with expedited service is essential.

POLICY OPTIONS

Parking automation provides many possibilities to reward or penalize different behaviors. Automation also allows a high level of flexibility, where differing policies may be implemented at different parking lots and land uses. For instance, carpools and vanpools could receive preferential treatment. For instance, a TMA policy might provide carpools with free parking,

waiving the $0.50 per day charge. For "tight-supply" applications, NextSpace could prioritize convenient spaces for carpools and employees, guiding solo drivers to less desirable lots.

Likewise, the TMA could decide to discourage mid-day cold start trips (when the vehicle sits for more than one hour before being re-started) by directing the parking system to add charges for multiple exits per day. As yet another example, transient parkers could be granted ten free visits, after which $0.50 per day parking charges would apply.

SRP WORKFORCE HOUSING PARKING

In the event that in-fill housing is built for employees, residential parking cost should be "unbundled" from rent. Exposing the hidden cost reduces demand, sometimes shrinking two car households down to a single car. Developers should be allowed to reduce minimum parking requirements under such a scheme. The cost of parking for new residential construction within SRP should reflect market conditions. If advanced circulator transit were provided, SRP employee residents could stow their less frequently used cars at lower cost within gated SRP office lots. (12)

RESIDENTIAL SPILLOVER

With TMA parking pricing at $0.50 per day, there is little chance of SRP employees parking in nearby Palo Alto residential neighborhoods to save money. Should such spillover ever become a problem, residential parking permits could be used to discourage such behavior. (13)

CAPITAL COSTS

Rough capital costs of $5.9M are detailed in Table 1:

	Costs	Notes
Parking study	$200,000	
McGann control SW	$400,000	
264 PCs: video, LCD, SW, etc.	$1,056,000	@ $4,000. SeeCar SW
Software customization	$200,000	One burdened person year.
264 gates, including concrete	$792,000	@ $3,000. Amano AGP 1700.
264 vid. cam., mounts, lights, cabling	$528,000	@ $2,000, includes illumination
132 entrance/exit modifications	$264,000	@ $2,000 for re-striping, signing
132 network/power cable sets	$396,000	@ $3,000
3 large electornic message boards	$90,000	@ $30,000
Merge some parking lots		
Concrete	$500,000	@ $30,000 per lot, 30 lots
Landscaping	$500,000	
Design, install, project mgmt	$985,200	20% overhead
Total	**$5,911,200**	

Table 1: Capital Costs

Some notes about the costing:

- Many quantities are multiples of the 132 access driveways in SRP.
- Prominent electronic message boards are placed at Page Mill/El Camino, Page Mill/Foothill, and Arastadero/Foothill.
- Where two parking lots are within 30 feet of each other, they may be joined by two asphalt lanes for about $30K. (From Brian Peoples.)
- Cost of hardware for the ruggedized personal computer (PC) is less than $2,000. National Instruments sells inexpensive ruggedized PCs.
- It may be possible to connect the access/egress PC to an employer network via WiFi, reducing the cost of cabling above and below asphalt, but this presents more of a security challenge.
- There is no contingency item in the budget, so the budget is a bit optimistic.
- Parking lots may be required to be brought up to current building code. This could entail new lighting, new islands with less impervious surface / more greenery, and could require additional ADA (American's with Disability Act) accessible parking.

PHASING

SRP corporate Facility Managers are crucial to the scheme's success. They must assist in the design of the system, scheduling the phases, and assisting in mid-course implementation modifications. Such a collaborate design process will be facilitated by the formation of a TMA.

The phasing should start with a few large employer corporate campus parking lots, and gradually expand the scheme. Start with $0.25 daily parking fee, and increase this to $0.50 after six months. Willson urges caution in modifying behavior:

- Allow behavior to adjust over time
- Allow for incremental refinement
- Provide advance notice of changes
- Provide grace periods (13)

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10) Dambach's individual parking space monitoring and guidance system: http://www.tcsintl.com/single_space.htm. Directs cars to available parking spaces.
11) EPA's Best Workplaces for Commuters division has compiled a spreadsheet with 41 TDM case studies that can be found at: http://www.cities21.org/tdm.htm.
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